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THE WATER-ENERGY NEXUS AND THE APPLICATION OF GREEN TECHNOLOGIES

as part of the

INNOVATION FOR INCLUSIVE DEVELOPMENT LEARNING (IID) SEMINAR SERIES

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Venue: Menlyn Boutique Hotel, Pretoria

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the Academy of Science of South Africa (ASSAf)

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The Academy of Science of South Africa (ASSAf) was inaugurated in May 1996. It was formed in response to the need for an Academy of Science consonant with the dawn of democracy in South Africa: activist in its mission of using science and scholarship for the benefit of society, with a mandate encompassing all scholarly disciplines that use an open-minded and evidence-based approach to build knowledge. ASSAf thus adopted in its name the term 'science' in the singular as reflecting a common way of enquiring rather than an aggregation of different disciplines. Its Members are elected on the basis of a combination of two principal criteria, academic excellence and significant contributions to society.

The Parliament of South Africa passed the Academy of Science of South Africa Act (*No 67 of 2001*), which came into force on 15 May 2002. This made ASSAf the only academy of science in South Africa officially recognised by government and representing the country in the international community of science academies and elsewhere.

DEPARTMENT OF SCIENCE AND TECHNOLOGY AND ACADEMY OF SCIENCE OF SOUTH AFRICA

INNOVATION FOR INCLUSIVE DEVELOPMENT LEARNING SYMPOSIUM

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WELCOME AND OVERVIEW

Mr Stanley Maphosa (International and National Liaison Manager, Academy of Science of South Africa [ASSAf]) welcomed participants to the seminar and invited a round of introductions. The seminar was the second in a series of three seminars on topical issues organised by ASSAf on the request of the Department of Science and Technology (DST).

Mr Imraan Patel (Deputy Director General, Socio-Economic Innovation Partnerships [DST]) indicated that, over the last five years, DST has been confronted by the ongoing discussion about the science system's support of efforts to think strategically about future directions. As part of the broader debate about how science, technology and innovation (STI) inform policy and practice, DST identified the need to create a dedicated facility that bridges the divide between the science policy and practice under the umbrella of the IID programme. The programme aims to inform and influence service delivery and other choices based on research findings and international best practice. This has been included in the current strategic plan and there were very particular indicators around it. The IID programme and the effectiveness of these seminars will be reviewed at the end of the current five-year cycle. The concept of decision support has received a much more traction as a result of the DST's White Paper on STI, which was finalised recently.

The idea for the seminar, a forum for open thinking, emerged during a bilateral discussion with partner departments, including the Department of Environmental Affairs (DEA), where the need to think strategically and in collective terms about technologies and technology choices was raised. It is anticipated that this seminar would provide the initial conversation around this issue and the process of taking nexus thinking to nexus action and incentivising nexus thinking would be taken forward in the context of the DST bilateral discussions.

KEYNOTE ADDRESS 1: SUSTAINABLE DEVELOPMENT WHEN YOU ARE ENERGY RICH, BUT WATER POOR - MR PETER LUKEY, CHIEF POLICY ADVISOR: STRATEGIC ENVIRONMENTAL INTELLIGENCE, DEA

Mr Lukey's presentation suggested that business as usual will not resolve the problems caused by doing business as usual, and that it is important to start looking at new ways of thinking.

Pre-2000, coal was considered as constituting South Africa's energy wealth, but this wealth needs to be completely re-evaluated.

South Africa has a tremendous energy wealth that does not pollute water or contribute to climate change, and the country has the basis to manufacture all the necessary components. The coal reserve is pitifully small compared to the country's solar reserve. South Africa has the second highest solar insolation in the world and almost twice the solar resource of Germany where solar photovoltaic (PV) is close to cost competiveness and there are almost 40 Gigawatts (GW) of installed solar PV capacity. South Africa also has an enviable wind resource and economically viable opportunities for wind energy in most areas of the country. Germany has 46 GW of installed wind capacity (equal to all the energy produced by Eskom) in comparatively weak wind conditions.

South Africa is a water poor country. In terms of what is reported to the United Nations (UN) in respect of Sustainable Development Goal (SDG) #6 that aims to ensure availability and sustainable management of water and sanitation for all, South Africa's level of water stress is 104.7%. This means that water usage exceeds available developed safe yields including ground water, yet investment is still being planned around the weather and how much rain will fall even though climate change predictions show that there will be more droughts.

South African agriculture is the biggest direct user of water and 37% of water in South Africa's urban piped water systems is lost to leaks or is used illegally. Although South Africa's annual rainfall is half the world average, our per capita water consumption is almost 30% higher than the world average. This raises questions about how precious water really is, why 2000-year old technology is still being relied on to deal with human waste and whether real efforts are being made to develop technologies to save water.

If the country is energy rich and water poor:

- Technologies for sanitation, many of which are invented in South Africa, should become standard
- Large shallow dams for water storage should make way for underground storage that is pumped to the surface when needed. The National Aeronautics and Space Administration's (NASA's) Gravity Recovery and Climate Experiment (GRACE) satellite mapped global aquifers over a period of 15 years. This rich source of data has led to new science, but not a single paper has come from South Africa. The exposed water in existing dams, which are relatively dead ecologically, can be protected by floating solar panels. This is being done on a huge scale in China and India and has the potential to complement the country's hydropower.
- Phosphate should be removed from the water before it reaches any rivers and dams, and the phosphate recycled. A circular economy that continues to re-use the phosphate should be introduced.

South Africa's National Development Plan (NDP) talks about a 50% increase in land under irrigation but not a 50% increase in water for irrigation. This will require a shift to smart irrigation using appropriate technology.

Real innovation will require a reassessment of the country's actual energy wealth, which lies in extensive solar and wind resources, innovation and the thousands of unemployed people, focussed around a common strategic goal.

KEYNOTE ADDRESS 2: GLOBAL PERSPECTIVE ON THE WATER-ENERGY NEXUS - CHALLENGES AND OPPORTUNITIES - PROF. STEVEN J KENWAY, ASSOCIATE PROFESSOR, SCHOOL OF CHEMICAL ENGINEERING, UNIVERSITY OF QUEENSLAND, AUSTRALIA

Australia, like South Africa, is water poor and has tremendous energy reserves. Consequently, the nation has invested significantly in integrated water management.

The first articulation of the water-energy nexus came from the American scientist, Abel Wolman, when in 1965 he published a landmark paper that used the concept of urban metabolism to simultaneously deal with shortages of water, pollution of water and air, as well as public economic decisions. He concluded that 'there is no shortage of water, however, there is a need for long-term thinking'. His concept went silent for about 40 years until a greater rush of publications began about 15 years ago.

California is one of many places in the world where the economy is constrained both by water and energy. The Californian government has mapped all the elements of the water-energy nexus and done good work to show how much energy is connected to water. The University of Queensland's research group on water-energy-carbon used this framework for its work with water and energy utilities in South-East Queensland, focussing on the city and not agriculture. Dr Gustaf Olsson of the International Water Association (IWA) characterised energy intensity through the urban cycle in Sweden and the IWA has been progressive in looking at solutions and technologies through the whole cycle.

During the millennium drought in Australia 80% of the population was in a similar situation to that of Cape Town currently and saw rainfall reduction of 16% driven by climate change that led to a 55% reduction in stream flow. Perth shifted very quickly to desalination solutions and a record AUD 4 billion was spent in South-East Queensland within about three years with significant investment in major recycling and desalination infrastructure. A national water study to assess the energy consequence of the shift to infrastructure showed that the energy density of water would almost triple by 2030. Rising energy use in urban water, rising energy costs, and national greenhouse gas (GHG) targets became a challenge that required a paradigm change in the thinking. The University of Queensland's research group has developed water-energy trajectories comparing some Australian cities, but water-energy nexus research has not looked at decadal trends over time anywhere in the world. The pathway to efficiency requires becoming more efficient with water as well as with energy.

At the World Water Forum 2015 in Korea, the International Union for the Conservation of Nature (IUCN) presented a mapping of the location of energy infrastructure and water stress in Asia to highlight the impact of the water-energy nexus on the continent. Long-term water stress is expected across Asia and this will impact on energy infrastructure, which needs water for cooling. It is forecasted that up to 3.4 billion people could be living in water-stressed areas of Asia by 2050, constraining economic growth and development. Parts of India are becoming drier. India has higher water loss rates than South Africa and rapidly growing cities. Many of the cities draw on ground water that is getting deeper and requires more energy for pumping, and is likely to run out.

World Bank data shows that on average energy costs more than 40% of the total operating cost (including labour) for more than 40% of utilities. If these figures are projected forward with the higher cost of energy, a bigger city, limited ground water and dry climate, more than 90% of cities' total operating budgets will go to energy.

In terms of challenges, opportunities and forward pathways:

- Funding, regulation and policy are currently in isolation and a shift to comprehensive simultaneous policy, regulation and funding is needed.
- Unplanned 'trading' and problem-shifting need to be addressed through systemic planning and efficiency.
- It is necessary to move to scale - based solutions (a mixture of centralised and decentralised solutions) instead of problem solving being driven by water and energy utilities.
- Data and reporting need to be interlocked and coordinated instead of being scattered, which makes it difficult to see trends.
- Quantified urban performance underpinned by clear metabolic boundaries is needed.

- There is an absence of optimisation studies, which are needed to guide urban blueprints (regional and city plans).
- Water - related energy management targets need to be set to drive coordinated action across government and industry.
- Research needs to be coordinated instead of isolated.

Complementary water and energy policy and strategies, which provide 30-year plans with opportunities to achieve synergies between water and energy, have been put in place by the Minister for Water and Energy for South-East Queensland.

A Water Research Foundation project on integrated water and electric utility planning was run in the United States and looked at how water and electric utilities could engage in integrated planning together with an understanding of related benefits. A number of case studies were done globally and benefits including cost savings, uncertainty management and cross sector solutions were identified with the points of entry being energy cooling, renewable energy generation in water/wastewater and end-users providing huge efficiencies of scale. It was also found that cross-utility partnership and planning is uncommon, language and terminology is challenging, political and regulatory barriers are numerous, viewpoints differed and there was a lack of awareness of linkages and opportunities.

There have been huge shifts in technology with many emerging technologies at various scales. Examples include waterless clothes- and dish-washers, and recirculating showers. The challenge is to identify and prioritise those technologies that drive down water as well as energy consumption. At city scale, integrated resources recovery uses the capacity in the wastewater treatment system and anaerobic digesters to generate gas, transport fuel and electricity, and exploit hot as well as cold water for different purposes to become the resource factories of the future. In terms of architecture, questions are asked about how much energy could be saved if all the elements of rainwater harvesting, water reuse, green roofs, urban agriculture, hydropower, evaporative cooling and thermal storage are used.

Metabolic boundaries support quantitative performance indicators of cities including the level of waste. A three-dimensional volumetric boundary has been created around Melbourne and every drop of water coming in is tracked. If the city was redesigned to have the perfect technology, rain falling on the urban footprint could have met 400% of the water demand of the city. Currently, the city is only using 0.5% of the rain water, 7% of the wastewater and 2% of the storm water.

The water-energy nexus has significant security and cost implications, but much can be done to problem-solve. It will be necessary to shift towards integrated systemic collaborative water-energy planning, have forward-looking, scenario-based assessments, identify high risk regions, assess alternative water opportunities, and have a mix of demand and supply solutions particularly considering energy associated with water end use.

DISCUSSION AND Q&A

Question: Increased costs of electricity have led to industry making an effort to be more energy efficient. Would increasing the water tariffs make a difference?

Response, Prof. Steven Kenway: Tariffs are complex, but part of the solution. In Australia there are stepped tariffs. The more you use the more you pay, and there are fixed tariffs and volumetric tariffs. Many water utilities complained because they could not generate revenue without increasing prices. There has been a shift towards decoupling of utility revenue from volumetric sales. In the United States, there is decoupling of energy company revenues from volumetric sales. It is important to create an economic framework for resource efficiency that addresses tariffs. Sydney Water partially won the Stockholm Water Prize partly because the economic regulator took AUD 250 000 from them and paid the utility for meeting water efficiency targets. However, communities do not respond well when they save water but still have to pay more for the water they use.

Response, Mr Peter Lukey: It is not in the nature of water and energy supply infrastructure to manage demand. This has been seen in relation to Eskom. When there were energy savings and increased energy efficiencies, Eskom implemented massive increases to cover the shortfall. In South Africa, there is a free basic water supply and tariffs have to pay for this 'free' water. It comes down to the systems idea.

Comment: Ideally, cities should be able to harvest rainfall and have reservoirs as a central feature. The form that future cities take impacts directly on the water-energy nexus.

Response, Prof. Steven Kenway: The question of the urban form requires creative thinking. It is critical to have storage within the city in order to harvest water that is falling on the city. A number of major urban developments in Australia are centred around an urban lake. Singapore has developed a barrage harvesting system to create an urban lake, with multiple benefits of urban cooling, recreation and so on.

Response, Mr Peter Lukey: Some exciting work is being done around city planning and urban infrastructure. Green buildings, such as the DEA building in Pretoria, incorporate architecture to do rooftop harvesting, underground water storage and grey water harvesting systems. However, a fortress mentality of securing water for selected use should be avoided. Recent research done around the Gauteng cities showed that people regard the lack of parks and recreation (green spaces) as the municipalities' biggest failure. The idea of creating lakes as areas of beauty and ecological infrastructure for water security has not been explored and is very exciting.

Question: Why is it that the water-energy nexus is not approached from a system thinking perspective?

Response, Prof. Steven Kenway: The scientific process has driven a lot of science to be very reductionist. There are a lot of barriers to system based science. The lack of using system science is why it is so difficult to respond to things such as climate change. Young scientists are not adequately trained in multi-disciplinary approaches, making it difficult for them to progress into inter-disciplinary science, and it can be difficult to publish in inter-disciplinary journals. Systems tools are very powerful and are being used and metabolism concepts are perfectly situated to systems dynamic models, which are being used.

Response, Mr Peter Lukey: Planning is done in silos. The Department of Water and Sanitation (DWS) is finalising the water master plan. DWS is leading this process but wants everybody to be involved. Other departments say that it is DWS's mandate to develop this plan. There is no engagement around the synergistic solutions. The reality is that DWS's mandate effectively ends at municipality level. They are a supply side organisation that is being asked to plan for the nation without thinking about demand. Water security is not

the work of a department but the work of a nation. The best opportunity to do this was the NDP, but this has a chapter on water and a chapter on energy, and ignores the nexus. The real chance of having a high-level strategic discussion around the nexus issue and systems thinking is being missed. The National Water Security Framework for South Africa is being developed by the National Planning Commission, but once again, this is purely water - based, and strongly supply side driven, presenting only one part of the equation.

Question: The terms, 'comprehensive, simultaneous policy, regulation and funding, systemic planning and efficiency and evidence based solutions' were used in the presentations. How can these be integrated into the South African debate, particularly in terms of research focussed on the grand challenges and the NDP, to trigger thinking towards achieving the 2030 goals?

Response Prof. Steven Kenway: Integrating these ideas is very hard and not even being done in Australia. Different parts of this occur in many different places, but it is necessary to progress in all areas simultaneously. South Africa has a good quality and very innovative water industry. Part of the solution is to bring it together with the energy sector. More training is needed across the water-energy nexus.

Comment: The missing link in the water-energy nexus discussion has to do with the human aspect, particular the population explosion.

ROUNDTABLE: GREEN TECHNOLOGIES FOR THE WATER-ENERGY NEXUS

The Water-Energy-Food (WEF) Nexus: Climate Risks and Opportunities in Southern Africa - Dr Sylvester Mpandeli, Research Manager, Water Utilisation in Agriculture, Water Research Commission (WRC)

Southern Africa, as a region, faces water, energy, and food insecurities. A Water-Energy-Food (WEF) nexus approach could unlock positive synergies needed to catalyse regional development. The WEF nexus offers a different way of thinking as well as inclusiveness. Countries in the Southern Africa Development Community (SADC) share hydrological systems and as such are responsible for building relationships at technical, policy and political level. It is important to demonstrate the collaboration that needs to take place at transboundary level across the SADC region.

In developing a regional nexus framework, a conceptual and methodological model was used to assess SADC regional WEF nexus (policies, institutions, and constraints), and policies relating to regional agricultural policy, the regional strategic action plan and the Southern African power pool were reviewed. Adoption of the nexus approach offered opportunities for regional integration, inclusive development and socio-economic security. Some SADC countries (Mozambique & Democratic Republic of Congo) have water resources capable of generating enough hydropower for the whole region while others are water scarce. Integrated development would therefore be beneficial to water resource management at the basin level. However, implementation of the WEF nexus framework in the region faces major challenges. Despite institutional and policy achievements, little has been done to implement the WEF nexus at national and basin level and integration of the WEF nexus is hindered by a lack of commitment by member states and policy that fails to oblige countries to conform to the regional master plan.

The integrated WEF nexus assessment model was developed and takes into account regional challenges (such as recurring droughts, political instability, and socio-economic challenges), governance issues, areas where action is required and outcomes.

The study concluded that the WEF nexus offers opportunities to effectively attain sustainability through interdisciplinary cooperation at a regional level, particularly in southern Africa, where resources are shared. It also offers inclusive, transparent, intergovernmental approaches for all stakeholders and supports the UN SDGs, using scientific and evidence - based policy, monitoring, assessment, and cooperation models. The shared and transboundary nature of SADC's resources implies that there are greater gains and more prospects of success if developmental efforts are focused at the regional level as opposed to the national level. Unlocking development at the regional level would ultimately allow greater progress at the national level and allow for genuine integration and inclusive development. Incorporating the nexus thinking in the development of agriculture investment plans would be worthwhile for sustainability.

Water-Energy Nexus: How Green can it be? - Prof. Godwell Nhamo, Chief Researcher and Exxaro Chair in Business and Climate Change, Institute for Corporate Citizenship, University of South Africa (UNISA)

Africa is a dark (unlit by electricity) and water scarce continent. The water-energy nexus has to be considered in relation to the twin 2030 agendas for South Africa's National Development Plan (NDP) and the UN Agenda for Sustainable Development enshrining the 17 Sustainable Development Goals (SDGs), as well as Africa's Agenda 2063. SDG #6 (ensure availability and sustainable management of water and sanitation for all) and SDG #7 (ensure access to affordable, reliable, sustainable and modern energy for all) require solutions that are able to balance water and energy availability for all with sustainability and affordability. The nexus cannot be addressed outside the context of sustainable development. Finance, governance and innovation are the enablers of the water-energy nexus.

The World Bank's publication, 'Modelling the Water-Energy Nexus: How do Water Constraints Affect Energy Planning in South Africa' makes some interesting points. The amount of water consumed by the energy sector is a small percentage of all water use nationally. Virtually all water in South Africa is allocated and future demands will require new infrastructure to avoid taking water away from existing users or compromising social and ecological sustainability in a specific catchment. National climate change policy will have consequences for national water resource and energy planning and it will be necessary to deal with high water consumers in agriculture, find ways to ensure that water is not wasted and encourage the construction sector to go green.

Key recommendations for the future are:

- There is no choice but to have water-energy efficient technologies, starting with the agriculture sector.
- New generation water and energy policies, as well as legislation that speaks to the water-energy nexus, are needed.
- Water saving and efficiency technologies need to be socially acceptable.
- More precise predictions on climate change and extreme weather events are needed.

Water-Energy Nexus: Wastewater Renewable Energy - Prof. Ochieng Aoyi, Director Research and Development, Botswana International University of Science and Technology (BIUST)

The South African White Paper on National Water Policy sets the context of the discussion on the water-energy nexus, the interrelationship between water and energy.

South Africa is a water scarce country and one of the world's leading environmental polluters. It is also the research powerhouse of Africa and has a material - based economy. In order to become the global innovation hub in Africa driven by the knowledge economy, it will be necessary to do more with less through technology transformation (from raw material to data) by developing economic clusters (a 'Water Valley' similar to Silicon Valley in the United States) and valuing research, and using integrated thinking to integrate processes.

A study on the uptake of Green Energy in South Africa undertaken by Prof. Aoyi found that:

- There is a lack of employees with green energy skills.
- Training programmes on green energy skills are inadequate in most provinces of South Africa.
- There is a lack of green energy policies and a lack of funding to implement green energy.
- Training is required speciality for municipalities to enable them to apply the concept of water-energy nexus.

South Africa needs an economic cluster or 'Water Valley' that brings together industry, university and government sectors or sub-sectors and serves to integrate all the data, technologies and innovations to come up with products.

Human-Technology Interactions: The Social Side of Innovation - Prof. Andrew Thatcher, Professor and Chair, Industrial and Organisational Psychology, University of the Witwatersrand

The water-energy nexus problem is primarily a human problem that necessitates a human sciences approach to help understand and find solutions.

Prof. Thatcher and many other researchers around the world are studying issues of technology and how human beings interact with the technology to produce sustainable solutions. There is a plethora of technologies and there are thousands of different ways to intervene using technology, and although there are pockets of success, failure is common. This highlights the need to look deeper at how human-technology interactions take place.

The following questions should be asked when making decisions about the type of technologies to put in place when intervening:

- If there is a technology, do people know about it? Scientists are very good at coming up with solutions, but are not very good at telling people about them and promoting them.
- Do people actually want the technology? One example is that of a rural village that did not have any water. To give the villagers access to water, a few wells were dug and water could be manually pumped to the surface using a rotating device that children could play on. However, no one was using the pumps. A study done to find

out why the villagers were not drawing water from the wells found that the women who were responsible for drawing water preferred to walk to the river because this provided the opportunity to socialise with other women.
- Can they access the technology? This is largely an affordability issue and can also be a transport problem.
- Can they use the technology in a way that it saves the resources it is intended to save?
- Can they abuse it, or use it in a way that counteracts its intention?
- Can they maintain it? Efforts are wasted if the people the technology is intended to help do not have the skills or the resources to maintain the technology.
- What happens when the technology reaches the end of its life? Can it be repurposed or re-used?

DISCUSSION AND Q&A

Question: Much has been said about infrastructure technology linked to existing infrastructure, improving what exists. In South Africa, the majority of society is excluded from access. If there is access, it might not be used properly or be broken. In communities, there is a local dimension to these problems and scale and context really matter. The challenge is that a variety of solutions are needed in a variety of places. There is no silver bullet. How should scale and context be dealt with and how can inclusiveness be created? How are value chains of water and energy use understood and how does this cascade through the system?

Response, Prof. Godwell Nhamo: There is global innovation and context specific innovation. There is a need for context specific innovation and the acceptance of technologies by those who will use it is essential.

Response, Prof. Andrew Thatcher: My work has been looking at how to integrate technology cycles with natural cycles and what nature does to ensure sustainability. Nature provides a variety of solutions called diversity, which is important in all contexts. Diversity has many different advantages. It fits into local contexts and uses local resources. I agree that there is no silver bullet.

Response, Dr Sylvester Mpandeli: With regard to technology adoption and implementation, the WRC has noticed that it is difficult to convince farmers to use technologies that do not assist them to improve production and increase crop yields and ultimately make a profit.

Response, Mr Peter Lukey: The social acceptance of technology must be aimed at and apply to where the real problems lie, and the technology must be aspirational and explained to the users. The concept of ghettoisation of technology (such as electric toilets for the poor and flushing toilets for the rich) has to change.

Question: Science does not communicate well and scientists cannot provide all the answers and solutions that government requires. What is missing in the system is knowledge brokering and transformational learning, specifically around technology and context. How should this be addressed in the discussion around technology and innovation?

Response, Prof. Andrew Thatcher: The problem is that most people are flooded with too much information. The answer is not just to give them more information but to change the knowledge systems to filter information appropriately.

Question: Should the knowledge that has already been acquired about the water-energy nexus be used instead of generating more of the same knowledge? It is necessary to move forward using the interdisciplinary information already available.

Response, Prof. Andrew Thatcher: There is a move towards more interdisciplinary work. Funding agencies are favouring interdisciplinary work over single disciplinary work. This is a good move but it will happen slowly. The funding agencies should force people to think in an interdisciplinary way in calls for proposals.

Response, Dr Sylvester Mpandeli: Research proposals need to address multi-disciplinary systems. The WRC's biogas project, which not only generates energy but also produces slurry which is being used as fertilizers for back yard vegetable production; it was noted that the biogas also creates job opportunities in local communities, and this has attracted the attention of politicians in some of the provinces and the project is now at implementation level.

Response, Prof. Ochieng Aoyi: We must integrate resources and cannot afford to work in silos. At a global level, countries and regions are coming together to work together for the common good. This model should be replicated at a micro level. In order to move forward, we need to have a common understanding of what needs to be done using the data already available rather than generating a lot of data that may not be helpful to solve the current problems. An economic cluster (that goes beyond the Research Chairs and Science Parks) is needed that allows various sectors to work together to create value out of the data that is available. This will encourage interdisciplinarity and appreciation of the 'big' data generated by the Research Chairs and Science Parks.

Question: Education and re-education is a serious component of this discussion. Engineers and scientists are not being taught to think beyond the fields they work in. Unless this is changed and they begin to think in networks, scientists will continue have a limited view of the problems they address.

Response, Prof. Andrew Thatcher: I think it should be compulsory for every course at university, not just engineers, to include a module on systems engineering. We live in a systems world. Systems are even more important than history, which is just one of the systems that we are affected by.

Question: What do business and domestic capping of water and energy, decentralisation, off-grid solutions and systemic thinking mean for institutional arrangements and the current roles of institutions? An enabling environment and frameworks are being proposed by researchers, but are not being taken up because there are institutional blockages. Who should think through the actioning processes around institutional roles in enabling this way of working?

Response, Prof. Godwell Nhamo: The South African government actually has five and not three tiers. There are 42 national departments, yet implementation at local level (if we consider metropolitan municipalities that are well capacitated), is the responsibility of only ten Members of Mayoral Committees. Issues get lost in governance downsizing, or should we say right sizing. The inter-governmental framework does not resolve the problem either. For example, the law is there, but the law cannot substitute interpersonal relations within, between and among government departments. The top heavy governance structure needs to be downsized and more governance is needed at local level where

implementation happens. In short, the current government organogram that is top-heavy must be reversed.

Response, Prof. Andrew Thatcher: Our institutions need to change. Donella Meadows has done interesting work on levers of change, which builds on the work of natural systems change. Institutions will naturally change slower than the mechanisms underneath them, but there are ways (system methods) to change the institutions.

Response, Mr Peter Lukey: The DEA has been trying to be a driver of sustainable development and within this conversation it is essential to focus on the water-energy nexus and the relationship with DST and other partnerships become fundamental. However, the educational systems make this very difficult because people are trained to work and think in silos. This creates social barriers, which are a challenge.

Response, Prof. Steven Kenway: For every 100 papers on the water-energy nexus, 90 focus on technologies, 8 on the environmental implications and about 2 on economics, but none on governance. There is a logical progression that is desperately needed. At a World Water Forum it was mentioned that water and energy institutions in some parts of Africa were being decoupled because of accountability. If there is no water security, quality or delivery, then accountability has to be driven. There has to be a balance between integration for a whole system's performance and accountability of individual components. The sorts of studies on governance that are missing have to do with how the head of power that drives institutions achieves integration as well as accountability. Good science is needed to underpin the accountability and systems performance at levels of service around water security, quality, restriction levels and energy. Californians have done interesting work in this space. Test pilots are needed and it is important to create relationships between utilities. Donella Meadow's work (referred to by Prof. Thatcher) talks about different levels of systems intervention. At the lowest level, she says that the slowest thing to change is constants and parameters, which is actually about changing technology, while closer to the top level it is about the nature of information players and benchmarking, which are key.

Comment: It is good to have pilot studies but feedback from these studies is crucial.

Comment: The role of science communication cannot be emphasised enough. Science must be made accessible to consumers.

Question: To what extent has the private sector been engaged or should it be engaged in the discussion about the water-energy nexus? There is possibly a lot of scope in this area.

Comment: Research I am involved in is looking at landfill impacts and the information will be used to inform water and energy security. Working with the water-energy nexus requires an integration of methodologies.

Comments, Prof. Godwell Nhamo:

- A 'technology midwifery' centre is needed within DST to assess the technologies that are produced and advise government about these technologies in terms of which ones to adopt in liaison with the responsible standards body.
- In the water-energy nexus, the emphasis must be on water.
- In terms of preparedness to address the water-energy nexus, the following readiness pillars are needed: high level political and management buy-in and championing, the right institutions and legislation, capacity development, finance, science

communication, information and communication technology, networking and partnerships, research and development, programmes and projects on the ground, as well as addressing bottlenecks of intellectual property (IP) rights.

TURNING NEXUS THINKING INTO NEXUS ACTION - DR HENRY ROMAN, DIRECTOR, ENVIRONMENTAL SERVICES AND TECHNOLOGIES, DST

Dr Roman highlighted the following in relation to the water-energy nexus:

- Nexus problems are 'wicked problems'. Resolving a problem is one silo creates a further problem in another silo.
- It is important to think about how the resources that are currently available are utilised.
- The SADC industrialisation strategy as well as the population explosion need to be taken into account in the discussion on the water-energy nexus.
- It is important to consider socio-ecological systems thinking tied to economic planning when addressing sustainable development. Incremental changes will not be helpful. It is necessary to disrupt the system using a different approach.
- Water has power and must be used as a diplomatic tool.
- Integrated planning is essential.
- In terms of the science-policy interface using evidence - based policymaking, science must be communicated to policymakers and to the population at large.
- Impact of research needs to be considered in a similar vein to publishing research.
- Difficult questions need simple (easily understood) answers.
- Science parks should be part of economic clusters. DST is addressing technology parks and the Department of Trade and Industry has plans to implement eco-industrial parks incorporating green technologies into the operations of the industrial parks.
- The problems we currently face is human ones and need to be resolved by humans. There is a need to become solutions - oriented.

CONVERSATION

Mr Patel highlighted the following in relation to the title of the session, 'turning nexus thinking into nexus action':

- This group has bought into the notion that radically new ways of thinking are needed, but this is not the way to get nexus traction. To get more traction, it is necessary to frame discussions around wellbeing and understand that the crisis points that people face are different (the local context), and use this to build sustainable ecological systems that look at water, energy and food.
- It seems that any action that has to be taken must acknowledge that there are levels of action. The level at which there seems to be the most attention is national level, but speakers and participants have said that this is the weakest level and regional and local approaches are necessary. Resources need to be placed appropriately.
- Crises (such as the Cape Town water crisis) must be exploited to bring the nexus (integrated technology) approach to the fore. The crises are clearly not about technology but about issues such as poverty, inequality and unemployment, which have to be resolved before bringing the technology.

The following points were brought up in the conversation:

- Academics and science should have an influence on policymakers but policy direction should be decided on by those who understand the legal perspective, not by scientists. In some cases, research output should not have to be protected by IP because IP can be a hindrance to future development. IP needs to be exploited for economic benefit.

- The problem does not have to do with different sectors working together but with implementation of the nexus. For example, Eskom used to support the Rhodes University Institute for Water Research projects, but no longer funds water research because its primary function is energy production and it does not see a link with water. Transdisciplinary research is the way to go.
- From many engagements with organisations on a catchment and national scale, it is clear that the problem is not only about technology, however, the relational aspect is crucial. This takes time, requires trust and finances and is about learning, reframing and feeling enabled to implement and do. Different knowledge needs to be brought to the table.
- The focus should be on the latest technology options instead of persisting with inherited, defunct technology.
- Water comes from catchments. It is of primary importance that these are looked after, specifically from the water quality perspective. Besides the hard infrastructure, ecological infrastructure must be brought into the equation and be integrated. Ecological infrastructure needs to be operated and maintained with the same if not greater care than we do with built infrastructure. Much can be achieved through working wisely with nature and not against it.
- Resources in the SADC region should be used to address sustainability and the development of the region. Some countries in SADC have plenty of water and energy, but are not concerned about those that do not have these resources. The problem is that countries are concerned about themselves and do not consider other countries.
- South Africa is a water scarce country, yet municipalities are one of the primary polluters of water resources.
- Government gives a lot of money to train people in wastewater management, but graduates remain unemployed. A database of all students qualified to work in the water sector needs to be developed.
- The right institutions are in place and financial resources are available (from banks, municipalities, industry and other funders) to address the water-energy nexus, but scientists need to be more aware of what is available and what capabilities are required to start transitioning research to innovation. Scientists tend not to be entrepreneurial and business oriented. This and other fundamental issues in the system need to change before talking about a lack of funding. More effort must be made to ensure that the scaffolding that is required is in place. For example, it is important to be aware of what the Technology Innovation Agency (TIA) requires in order to transition green technologies and move them to market. Innovators moving out of academia must be business ready and not only technologically ready.
- Not enough is said about implementation. An innovation is only an innovation if the market shows that it is being used. Innovations are counted the minute a paper is written or a patent is applied for. Patents on shelves are of no use to the public, we need to drive a behaviour change that moves beyond patenting and consider how we develop these into solutions that have socio-economic benefit. It is necessary to change the language before changing the system.
- The revised DST White Paper looks at bringing in the private sector as well as understanding the full national system of innovation as opposed to the public system of innovation, and what the public sector does right and where it can leverage in terms of capabilities in terms of implementation within the private sector. Not enough of this is being done and there is a tendency to blame industry for not investing in the right places and the private sector for only being seen to a particular few, but if there is no discussion with industry and the private sector, the agenda cannot be influenced. It is important to work together as opposed to blaming each other.

- Moving from ideas to implementation requires buy-in at the top and someone to take ownership and drive the process. Much is being said at seminars such as this, but unless proper ownership is taken, little will happen. A direct line to those in charge would be helpful.
- The need for integrated planning is clear. The Australian National Outlook, a document that drives all aspects of integrated planning for the Australian economy (infrastructure, water, electricity and so on) using a suite of 9 different models and experts across all fields, could be used as a template of how to start macro-economic planning to accommodate the nexus. The NDP could be repositioned to use more hard core science to drive the planning process. Although there is planning, the problems faced in the interim tend to derail the process and there is more crisis management instead of staying ahead of problems. Long-term planning is necessary and makes it more important to plan properly and get ahead of the game. Scientists need to work together and someone needs to take ownership for driving integration.
- There does not appear to be a timeframe or solid objectives for the water-energy nexus action. If this is the case, it will be difficult to monitor progress. There should be no need to discuss the same issues next year in seminars such as this. The key is to plan wisely by taking a systems approach and including all parties that should be at the table from the onset. Once a decision has been made at a certain level, it is important to move on and make provision at a later time to revisit where things went wrong. Institutions (the Council of Geoscience, for example) have to know whether they need to adjust their plans to accommodate water-energy nexus action, and reprioritise accordingly. Having the right people at the table from the beginning would provide a better opportunity to achieve timeframes going forward.
- When there are socio-ecological systems it is important to ensure that industry understands the benefit of supporting these initiatives going forward. DST facilitates the roadmaps that are developed (such as the National Water Resource Strategy) and does not own them. The problem is that the different domains have their own integrated approaches, yet the domains are crosscutting and know no boundaries, but have to merge with each other at some point.
- A dual approach (top-down as well as bottom-up approaches) is needed and private public partnerships are of utmost importance and need serious consideration.
- The terms 'data richness' and 'information pool' are used often, but if the country was data rich and had an information pool, the right decisions would be made. It is not so much about smart technologies as about smart choices. For many years there has been investment in the most expensive options, whether in energy, water or mining. It is time to start looking at resource management.
- Technology development is not only about new technologies, but rather about deploying existing technologies within different domains.
- Tough questions need to be asked if the problems are to be resolved and trust relationships between industry and government are of utmost importance if there is to be any progress.
- A 'nexus facilitation officer' is required. The importance of a relationship with government officials cannot be understated because it is very difficult to negotiate the way through the permits and regulations applicable to numerous government departments that are necessary when dealing with a nexus problem. There are regulatory bottlenecks and it is unfair to expect government officials on the ground to make decisions about such complex issues. A nexus facilitator would bridge the gap between the top and the bottom levels of government and help move things forward.
- 'Wicked' problems do not have single solutions and there is no grand plan to address the water-energy nexus. Research is not the solution. It is necessary to resolve primary

problems and then find out what the real problems are. This leads to the concept of a safe space to do research. It is important to ensure that there is enough money to get out of failure. It is advisable to encourage technology developers to fail frequently and fail fast, then move on. Drip feeding research does not lead to implementation.

- Ecological infrastructure talks directly to economics of water treatment. It is necessary to start looking beyond the municipal boundaries and upstream to the catchments, rather than focussing only on treating wastewater.
- It is necessary to understand the full system of innovation. DST has to integrate the systems of innovation in the various domains in order to give good advice to the other departments.
- DST is looking at the big data issue from various perspectives. Water is the central point of the discussion with the Water Research Commission about a hydrological centre for South Africa in order to collect, collate and analyse all hydrological data and transform it into information useable to an employee in a municipality.

CLOSURE

Mr Maphosa thanked the participants for attendance and their contribution to the discussions at this seminar, as well as the staff of ASSAf for having organised the event.

ANNEXURE A: LIST OF ACRONYMS

ASSAf	Academy of Science of South Africa
ARC	Agricultural Research Council
ARC-GC	Agricultural Research Council-Grain Crops
AUD	Australian dollar
BIUST	Botswana International University of Science and Technology
CIPC	Companies and Intellectual Property Commission
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
EWSETA	Energy and Water Sector Education and Training Authority
GHG	Greenhouse gas
GRACE	Gravity Recovery and Climate Experiment
GW	Gigawatts
HSRC	Human Sciences Research Council
IID	Innovation for Inclusive Development
IP	Intellectual Property
IUCN	International Union for the Conservation of Nature
IWA	International Water Association
IWMA	International Water Management Institute
NASA	National Aeronautics and Space Administration
NDP	National Development Plan
PV	Photovoltaic
SADC	Southern Africa Development Community
SANEDI	South African National Energy Development Institute
SDG	Sustainable Development Goal
STI	Science, technology and innovation
TIA	Technology Innovation Agency
UN	United Nations
UNISA	University of South Africa
WEF	Water-Energy-Food (nexus)
WRC	Water Research Commission

ANNEXURE B: LIST OF ATTENDEES

Title	Name	Surname	Organisation
Dr	Adrian	Abrahams	Agricultural Research Council-Grain Crops (ARC-GC)
Ms	Nadia	Algera	Academy of Science of South Africa (ASSAf)
Prof.	Ochieng	Aoyi	Botswana International University of Science and Technology (BIUST)
Mr	Gordon	Ayres	AGAMA Biogas (Pty) Ltd
Ms	Marlett	Balmer	GIZ
Dr	Heinrich	Bohlmann	University of Pretoria
Prof.	Chris	Buckley	University of KwaZulu-Natal
Dr	Siyavuya	Bulani	Academy of Science of South Africa (ASSAf)
Dr	Clinton	Carter-Brown	Council for Scientific and Industrial Research (CSIR)
Dr	Thandanani	Cwele	Companies and Intellectual Property Commission (CIPC)
Ms	Shereen	Dawood	Parliament of South Africa
Mr	Jonathan	Diederiks	National Research Foundation
Prof.	Bloodless	Dzwairo	Durban University of Technology
Mr	Eric	Economon	Agricultural Research Council (ARC)
Ms	Heather	Erasmus	Write Connection (Scribe)
Mr	Theo	Fischer	EScience Associates
Dr	Roula	Inglesi-Lotz	University of Pretoria
Prof.	Steven	Kenway	University of Queensland
Ms	Chantal	Kotze	Water Research Commission (WRC)
Ms	Jeanie	le Roux	Parliament of South Africa
Ms	Lianda	Lotter	Agricultural Research Council (ARC)
Mr	Peter	Lukey	Department of Environmental Affairs (DEA)
Ms	Precious	Lukhele	Department of Science and Technology (DST)
Dr	Tebogo	Mabotha	Academy of Science of South Africa (ASSAf)
Mr	Ncedile	Madlanga	Companies and Intellectual Property Commission (CIPC)
Dr	Hlamulo	Makelane	Human Sciences Research Council (HSRC)
Ms	Nonhlanhla	Mkhize	Department of Science and Technology (DST)
Mr	Thomani	Manungufala	Parliament of South Africa
Prof.	Regina	Maphanga	Council for Scientific and Industrial Research (CSIR)
Mr	Stanley	Maphosa	Academy of Science of South Africa (ASSAf)
Prof.	Sanette	Marx	North-West University
Dr	Paul	Mensah	Rhodes University
Prof.	Maggy	Momba	Tshwane University of Technology
Ms	Thato	Morokong	Academy of Science of South Africa (ASSAf)
Mr	Tshepang	Mosiea	Department of Science and Technology (DST)
Dr	Sylvester	Mpandeli	Water Research Commission (WRC)
Ms	Khothatso	Mpheqeke	South African National Energy Development Institute (SANEDI)

Title	Name	Surname	Organisation
Ms	Gracia	Munganga	The Innovation Hub
Dr	Sphumelele	Ndlovu	Indabuko Institute
Prof.	Godwell	Nhamo	UNISA
Dr	Luxon	Nhamo	International Water Management Institute (IWMI-South Africa)
Dr	Thakane	Ntholi	Council for Geoscience
Mr	Bernd	Oellermann	Department of Trade and Industry
Dr	Olusola	Ololade	University of the Free State
Mr	Imraan	Patel	Department of Science and Technology (DST)
Mr	Ephraim	Phalafala	Department of Science and Technology (DST)
Dr	Harrison	Pienaar	Council for Scientific and Industrial Research (CSIR)
Dr	Henry	Roman	Department of Science and Technology (DST)
Mr	Davies	Saruchera	International Water Management Institute (IWMI-South Africa)
Ms	Kelebogile	Seotloe	Academy of Science of South Africa (ASSAf)
Dr	Keneiloe	Sikhwivhilu	Mintek
Dr	Sabine	Stuart-Hill	Centre for Water Resources Research
Dr	Karen	Surridge	South African National Energy Development Institute (SANEDI)
Prof.	Andrew	Thatcher	University of the Witwatersrand
Ms	Mmaphefo	Thwala	Energy and Water Sector Education and Training Authority (EWSETA)
Dr	Graham	von Maltitz	Council for Scientific and Industrial Research (CSIR)
Ms	Henriette	Wagener	Academy of Science of South Africa (ASSAf)
Mr	Eugene	Zeelie	Durban University of Technology

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Academy of Science of South Africa (ASSAf) & Department of Science and Technology (DST)